technische universität dortmund

computer science 12

Bachelor Thesis

Chaotic Behavior of End-to-End Latencies

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In the study of real-time systems, usually upper bounds on the timing behavior are provided. That is, what is the *maximal* time that *any* job requires to finish its execution, called the worst-case *response time*. However, in many scenarios the timing behavior of jobs evolves over time and a certain pattern can be observed. More specifically, in their recent work, Thiele and Kumar [1] distinguish three different behaviors:

1. The observed response times reach a *fixed point*.
2. The response times show *periodic* behavior. That is, a repetitive pattern can be observed.
3. The evolution is completely erratic, i.e., *chaotic*.

Examples for the periodic and chaotic behavior can be found in Figures 1 and 2.

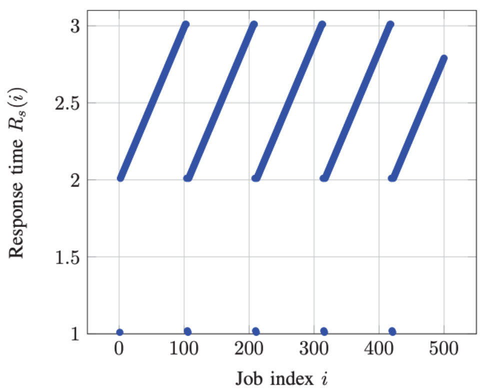

Figure 1: Periodic behavior of the response times observed in [1].

The work of Thiele and Kumar focuses only on the response time of individual tasks. However, in the context of distributed embedded systems, there is another metric that has recently received much attention — the *end-to-end latency* [2]. The end-to-end latency described the timing behavior of a data path travelling through a sequence of tasks. The chaotic behavior of such end-to-end latencies has to be further examined.

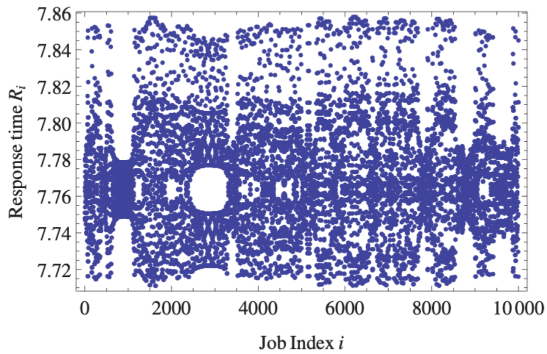

Figure 2: Chaotic behavior of the response times observed in [1].

In this thesis,[1] the student builds upon two already existing simulation frameworks. One is for data paths in the fixed-priority setup, the other one is for data paths in the Robot Operating System 2 (ROS2). In this simulation framework the end-to-end latencies of data paths need to be determined and presented in the form of diagrams. Afterwards, different observations and insights need to be formalized.

Required Skills:

- Interest in distributed real-time systems and end-to-end latency.
- Confident in Python programming.

Acquired Skills after the thesis:

- Knowledge about timing behavior in distributed system.
- Ability to present timing data in a clear and accessible way.

References:

[1] Lothar Thiele, and Pratyush Kumar. "Can real-time systems be chaotic?." 2015 International Conference on Embedded Software (EMSOFT). IEEE, 2015.

[2] Mario Günzel, Harun Teper, Kuan-Hsun Chen, Georg von der Brüggen, and Jian-Jia Chen. "On the equivalence of maximum reaction time and maximum data age for cause-effect chains." 35th Euromicro Conference on Real-Time Systems (ECRTS 2023). Schloss-Dagstuhl-Leibniz Zentrum für Informatik, 2023.

[1] Other suggestions and related topics are also welcome. Please do not hesitate to make an appointment.